Double-cone device with enhanced pressure amplification and reduced noise

BACKGROUND

The present invention relates to a double-cone arrangement for creating a pressure difference in a fluid flowing through the double-cone arrangement. Specifically, the present invention deals with a double-cone device that produces enhanced suction and reduced wear and tear.

A double-cone device comprises an entry unit, an exit unit, each of hollow frustroconical shape, and a central section referred to as orifice. When fluid flows through such a device, the orifice section exhibits suction properties. The suction property makes a double-cone device useful for many applications ranging from well pumping to separation processes such as desalination and deionization. The double-cone device is used in these applications for providing pressure amplification to the fluids used in these processes.

The double-cone device has been described in the US patent application US4792284 titled "Device for creating and exploiting pressure difference and the technical applications thereof". The double-cone device, as described in this patent, is illustrated in FIG.1.

Double-cone device 100 consists of two coaxial frustroconical sections, referred to as entry cone 102 and exit cone 104, held together by a cylindrical tube 110. Entry cone 102 is characterised by its length L_1, larger diameter D_1, smaller diameter d_1, and conical angle θ_1. Similarly, exit cone 104 is characterised by its length L_2, larger diameter D_2, smaller diameter d_2 and conical angle

θ_2. The region of minimum diameter between the two sections is referred to as orifice 106. Double-cone device 100 is fed with a feed flow that enters entry cone 102 and discharges out through exit cone 104. The feed flow can be any fluid i.e. either liquid or gas.

Cylindrical connecting tube 110 surrounds the area around the orifice. An inlet 108 on cylindrical connecting tube 110 allows suction of fluid from outside device 100 to be drawn into orifice 106.

During the flow within double-cone device 100, the feed flow undergoes a pressure variation that is a function of the geometry of double-cone device 100 and the fluid velocity at the inlet of entry cone 102. This pressure variation within double-cone device 100 is illustrated in FIG.2. As shown in FIG.2, the pressure within double-cone device 100 gradually falls as the fluid flows through entry cone 102 and then again rises in exit cone 104. The pressure is minimum at point (Z=0) within orifice 106. Also, pressures P_1 at the beginning ($z= - L_1$) of the entry cone 102 and P_2 at outlet point ($z= L_2$) of exit cone 104 are different. This difference in pressure $\Delta P = P_1 - P_2$ is referred to as the pressure-drop across device 100.

Behaviour of the feed flow or the pressure variation within the device is a function of various factors including geometrical parameters such as the conical angles of the entry and exit cones, external pressures at the inlet of the entry cone and the outlet of the exit cone. Specifically, higher the external pressure lower the pressure at the orifice. This results in a higher suction force at the orifice.

The performance of a double-cone device is usually measured in terms of its pressure amplification. Pressure amplification for a double-cone device is defined as the ratio of the pressure P_2 at the outlet of the exit cone to the pressure-drop ΔP across the device. Pressure amplification can be improved by reducing the pressure-drop or increasing the exit pressure. Another performance measuring parameter is the noise that is generated by a double-cone device. High noise level can lead to rapid wear and tear of the device and is generally considered to be environmentally unacceptable. Further, wear and tear of the device must be minimised so as to ensure that the device has a long lifecycle.

Various modifications have been made in basic double-cone design to improve its performance.

One such modification has been described in PCT patent application PCT/CH99/00403 titled „Double-cone for generation of a pressure difference". The patent describes a double-cone device comprising an entry and an exit cone connected by their small diameter ends to create an orifice. Further, the inlet is provided in the exit cone away from the orifice. The entry conical angle θ_1 has also been refined to be less than 5°. These modifications decrease noise and wear and tear of the double-cone device.

Another modification has been described in PCT patent application PCT/CH02/00134 titled „Double-cone device and pump". The double-cone device comprises an entry cone and an exit cone that are connected through a third cone. An inlet is provided in the exit cone. The smaller diameter ends of the entry cone and the third cone are connected to form an orifice. The conical angle of the third cone is less than that of the exit cone. Further, the conical angle of the

third cone must be in the range 1° to 5°. The introduction of the third cone and the positioning of the inlet away from the orifice reduce wear and tear. This is because the wall material is not subjected to a very high stress, as is the case with the original double-cone structure. Pressure-drop across the device also reduces, leading to better suction performance.

While various modifications have been made to the double-cone design, further improvements can be made to enhance the pressure amplification, reduce the noise levels and to stabilise the flow. For example, in the existing device under certain running conditions, the noise generation can reach the order of 110 to 115 decibels whilst the human noise tolerance level is around 85 decibel. Hence, there is a need for a double-cone device with lower noise levels. Further, in the existing double-cone devices, the flow within the device destabilises at high flow rates. Hence, there is a need to improve the design to stabilise the flow at high flow rates.

SUMMARY

An object of the present invention is to provide a double-cone device with enhanced pressure amplification.

Another object of the present invention is to provide a double-cone device with enhanced suction pressure at the inlet.

Another object of the present invention is to provide a double-cone device with reduced noise levels.

Another object of the present invention is to reduce the wear and tear in a double-cone device thereby increasing its lifetime.

Another object of the present invention is to improve the flow profile of the fluid flowing through a double-cone device.

Another object of the present invention is to provide a double-cone device with reduced working temperature.

Yet another object of the present invention is to provide a double-cone device, which can work efficiently at higher flow velocities, as compared to the existing double-cone devices.

The above objectives are attained by using a double-cone device having a continuous geometry. Specifically, the double-cone device comprises two frustroconical sections referred to as the entry cone and the exit cone. The entry and exit cones have a common smaller diameter face. This common diameter region is referred to as the orifice. Further, there is a plurality of holes on the exit cone close to the orifice.

The present invention achieves a higher pressure amplification, higher suction force and lower noise than that possible with the existing double-cone devices. This is achieved by using a continuous geometry and circular holes acting as the inlet for suction.

Holes are made in the exit cone, downstream of the orifice, but within the section of the exit cone with a diameter less than 1.5 times diameter of the orifice. The size of the

holes is less than or equal to half the diameter of the orifice.

The conical angle of the entry cone is less than or equal to 5° while the conical angle of the exit cone is less than or equal to 4°. This leads to reduction in energy consumption, reduced noise levels and higher flow rates.

In an alternate embodiment of the present invention, the holes on the exit cone away from the orifice are replaced by a porous section, modelled as region with infinite holes of very small size, between the exit cone and the orifice. This porous section is made of material such as ceramics.

Another alternate embodiment of the present invention comprises two frustroconical units referred to as entry and exit cones, an orifice region and an insert section. In this device, the insert section provides the path for the flow of the material to be sucked into the orifice region. Further, the exit cone angle is less than 2°.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiments of the invention will hereinafter be described in conjunction with the appended drawings provided to illustrate and not to limit the invention, wherein like designations denote like elements, and in which:

FIG.1 illustrates a double-cone arrangement described in Patent Number US4792284 titled "Device for creating and exploiting pressure difference and the technical applications thereof";

FIG.2 shows the pressure variation of the feed flow as it flows across the various sections of the double-cone device;

FIG.3 illustrates a continuous geometry double-cone device in accordance with the preferred embodiment;

FIG.4 illustrates a continuous geometry double-cone device with a porous section;

FIG.5 illustrates a double-cone device with an insert section.

DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention discloses a double-cone device with continuous geometry having a first tapering section and a second diverging section. A plurality of holes on the second section, beyond the orifice, facilitates suction into the device. The orifice is the point at which the tapering section ends and the diverging section begins, which is also the section of minimum diameter of the device.

FIG. 3 illustrates a double-cone device 300 of continuous geometry in accordance with a preferred embodiment of the present invention. Device 300 comprises two hollow frustroconical sections referred to as first tapering section (hereinafter entry cone) 302 and a second diverging section (hereinafter exit cone) 304 and a plurality of holes 306 on exit cone 304. The section of minimum diameter of device 300 is also referred to as orifice 308. Orifice 308 is also the exit section of entry cone 302 and entry section of exit cone 304. In a preferred embodiment, edge of the orifice should be sharp and the section should be perfectly circular. It should be apparent to one skilled in the art that edge can also be smooth.

Entry cone 302 is characterised by its length L_1, larger diameter D_1 and conical angle θ_1. Similarly, exit cone 304 is characterised by its length L_2, larger diameter D_2 and conical angle θ_2.

In a preferred embodiment of the present invention, entry conical angle θ_1 is less than or equal to 5° while the exit conical angle θ_2 is less than or equal to 4°. Values of L_1, D_1, L_2 and D_2 can be chosen corresponding to the chosen value of θ_1 and θ_2. It must be apparent to one skilled in the art that other values of the entry cone angle and the exit cone angle can be used without deviating from the scope of the present invention. However, for the provided choice of angles, the device achieves reduced noise levels and requires a lower energy input.

Double-cone device 300 is fed with feed flow 310 that enters entry cone 302 and discharges through exit cone 304. Feed flow 310 can be any fluid such as a liquid or a gas.

Feed flow 310 undergoes a pressure variation within double-cone device 300. Pressure within double-cone device 300 gradually falls as feed flow 310 flows through entry cone 302 and then again rises in exit cone 304. The pressure is minimum at orifice 308. Low pressure around the region of orifice 308, in the exit cone, allows material 312 from outside of device 300 to be sucked into device 300 through holes 306.

Holes can be of any shape such as square shaped, elliptical shaped and circular shaped. In a preferred embodiment, circular shaped holes are used. Further in the preferred embodiment of the invention, holes 306 are inclined in the direction of flow. It must be apparent to one skilled in the art that the alignment of the axis of the holes can be in

any direction with respect to the direction of the feed flow, such as normal to the surface of the exit cone or against the direction of the feed flow, without deviating from the scope of the invention.

Size of holes 306 is a function of feed flow material 310 and the size of orifice 308. The nature of the material that is to be sucked affects the size of the holes substantially. For example, if water is the material to be sucked, then the diameter of holes relative to the orifice diameter should be less than 0.5 and in absolute terms limited to <10 mm. If a non-Newtonian fluid is used, then the maximum diameter of the hole is limited to 4-5 mm. Further, for a non-Newtonian liquid, size of the hole is strongly dependent on the liquid's mechanical properties. In the preferred embodiment, the size of the holes < 0.2 times the orifice diameter is preferred. Small hole to orifice size ratio is preferred because if the ratio is too high then the stability of flow feed is adversely affected.

A plurality of holes is used so as to enable suction of a large amount of material. The position of the holes is kept as close to the orifice as possible because the suction force decreases as one moves away from the orifice plane. In a preferred embodiment of the invention, the holes are made at a section of exit cone 304 such that the diameter of the section is less than 1.5 times the diameter of the orifice 308.

In an alternative embodiment of the present invention, the entry section of the exit cone is made of porous material, instead of having the plurality of holes. This embodiment is described using FIG.4.

FIG.4 shows a double-cone device 400 comprising entry cone 302, exit cone 304, and a porous section 402. The geometry of the device is continuous and entry cone 302 and exit cone 304 are made of first material, which can be the standard material used for making double-cone devices, such as steel. Porous section 402 is made of a porous material such as ceramic or glass compounds. Porous concrete compounds are ideal for use in large double-cone devices. Other examples can be creation of porous section by chemical leaching of suitable materials. For instance, compounds composed of various alloys and plastics can be used to form the geometry and the porous section is then formed by subjecting the appropriate region to chemical or electrical attack. Feed flow 310 flows through device 400 moving from the inlet of entry cone 302 and discharging into outlet of exit cone 304. The discharge includes feed flow 310 as well as sucked material 404. Material 404 is sucked into device 400 through porous section 402.

For the porous material, hole sizes in the range of 50 to 500μm are used to provide a relatively silent suction (low noise levels) without reducing the suction capacity. Also, the diameter of porous section 402 should preferably be less than 1.5 times the diameter of orifice 308.

ADVANTAGES

The present invention provides enhanced pressure amplification and reduced noise.

Noise in a double-cone device is generated by a flow profile that does not respect the chosen geometry. In other words, the flow is not fully in contact with the double-cone walls. Also, in existing devices, the flow profile changes sharply as feed flow moves from the entry cone to the orifice

region. The present invention reduces this noise by creating a flow profile that more closely follows the wall geometry than in existing double-cone devices.

The continuous geometry of the double-cone device of the present invention causes the feed flow profiles in orifice 308 and exit cone 304 to remain in contact with the wall. This is because the continuous geometry does not allow flow feed 310 to become free, as is the case in existing double-cone devices. Hence, there is no drastic change in the flow profile as feed flow 310 moves from orifice 308 to exit cone 304. This improved flow profile leads to a significant reduction in the noise levels. Further, the improved flow profile reduces the wear and tear of the device. Additionally, improved flow profile allows the device to work efficiently at much higher flow rates than that possible with the existing devices.

Continuous geometry also leads to an increase in the pressure amplification as compared to the existing double-cone devices. The pressure amplification that can be achieved is a function of the flow regime within the double-cone. Specifically, the pressure amplification is a function of the axial flow velocity component. More dominant the axial flow velocity component, greater is the amplification that can be achieved. The continuous geometry reduces the tendency for the non-axial flow velocity components to increase in magnitude resulting in the increase in pressure amplification.

For example, a continuous geometry double-cone device results in around 50% increase in pressure amplification as compared to the performance of an existing double-cone device. The noise generated by the continuous geometry double-cone device also decreases. For the existing double-

cone device, a noise level of around 100 dB is generated while the continuous geometry double-cone generates noise of around 80 db. Specifically, in one experiment performed on continuous geometry double-cone of entry conical angle 5° and exit conical angle 2°, a pressure-drop of only 10 bar was developed whilst developing a pressure amplification of ~ 1.8 at a noise level of ~ 80db. This performance was ~ 50% better in pressure amplification than an existing device of comparable power.

Further, for $\theta_1 <= 5°$ the tendency of feed flow to rotate within device 300 is reduced. Rotation of the feed flow causes energy consumption. Hence, the provided choice of entry angle reduces the energy consumption due to rotation. The reduction in energy consumption results in increase in the pressure amplification that can be achieved.

For $\theta_2 <= 4°$, the flow profile of feed flow within exit cone 304 is stabilised. Stability in flow allows device 300 to be used efficiently even at higher flow rates. Energy consumed by device 300 is also reduced. Further, the noise generated by device is reduced.

For example, an existing double-cone device with entry conical angle 5° and exit conical angle 5° failed to perform efficiently when used as a specific hydraulic reverse pumping application. On the other hand, the double-cone device according to the present invention with an exit conical angle 2° worked without any problem.

The use of holes, as opposed to sliced sections removed from the exit cone in the existing double-cone devices, leads to an enhanced suction pressure downstream of the orifice 308. The suction force depends on the pressure that is generated in the neighbourhood of the orifice 308. The pressure in

this region is a function of various parameters. The parameters include geometry of double-cone device 300, pressure applied at the outlet of exit cone 304 and the position of inlets to suck the material into device 300. Specifically, if the inlet for sucking the material is closer to the orifice, the suction force is higher. This is because the suction force depends on the pressure existing in orifice 308. Lower the pressure in orifice 308, higher is the suction force. The pressure rises dramatically with distance from the orifice 308. Hence, to maximise the suction force, the suction inlet should be as close to orifice 308 as possible. The present invention utilises this fact to achieve higher suction by using plurality of holes 306 near the orifice.

Holes 306 are used since they can be placed closer to orifice plane than a slice taken out of the exit cone, as is the case with existing devices. When a slice is removed from the exit cone a free jet is created that does not re-establish contact with the exit cone walls until well into the exit cone. This problem is aggravated by flow speed. If the removed slice is too close to the orifice the jet speed is too high for the exit cone to exercise an adequate influence on the main flow near the orifice. Hence, the slice cannot be placed close to the orifice.

Another embodiment of the present invention uses an insert section between the entry and exit cone. This embodiment is shown using FIG.5.

FIG.5 illustrates a double-cone device 500 comprising two hollow frustroconical sections referred to as first tapering section (hereinafter referred as entry cone) 502 and second diverging section (hereinafter referred to exit cone) 504

and an insert section 508 instead of a continuous section with holes.

The conical angle of exit cone 504 is less than 2°. For this choice of the conical angle, the device achieves sharp reduction in noise. However, it must be apparent to one skilled in the art that other values of the exit cone angle can be used without deviating from the scope of the embodiment.

Feed flow 510 flows from inlet of entry cone 502 and discharges into outlet of exit cone 504. The discharge includes feed flow 510 as well as sucked material 512. Material 512 is sucked into device 500 through insert section 508.

Insert section 508 comprises a central hollow frustroconical section extending from the smaller diameter end of entry cone 502 to the beginning of exit cone 504. The smaller diameter of the central hollow section is matched to the smaller diameter end of entry cone 502 while the larger diameter end of the central hollow section is matched to the beginning of exit cone 504. Further, insert section 508 has a plurality of radial holes on the central hollow section for suction of material into device 500.

The use of insert section leads to substantial decrease in noise. For example, if the pressure at the outlet of exit cone is 19 bar, noise generated by the existing double-cone devices is 110-115 decibels (dB). On the other hand, the noise generated by device 500 is 85-90 dB.

While the preferred embodiments of the invention have been illustrated and described, it will be clear that the invention is not limited to these embodiments only. Numerous

modifications, changes, variations, substitutions and equivalents will be apparent to those skilled in the art without departing from the spirit and scope of the invention as described in the claims.